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Is furcation involvement in maxillary molars a predictor for subsequent bone augmentation prior to implant placement? A pilot study

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Abstract: AIM: The aim of this pilot study was to analyze the interfurcal bone height in relation to the possible need for subsequent sinus floor elevation in patients with advanced periodontitis and furcation involvement of first and/or second maxillary molars. MATERIAL AND METHODS: Seventeen dentate patients, who received cone beam computed tomography (CBCT) for detailed preoperative diagnosis and planning of surgical interventions at periodontally involved maxillary molars (17 first and 15 second molars), were consecutively recruited for the study. The minimal bone height in the interfurcal region was measured from CBCT and related to furcation involvement, residual bone above the root tips, and the clinical probing pocket depth (PPD). RESULTS: The minimal interfurcal bone height measured 4.1 ± 2.6 mm on average with 75% of maxillary molars having ≤ 6 mm and almost 60% having only ≤ 4 mm bone height left below the sinus floor. A higher risk for reduced interfurcal bone height of ≤ 4 mm was given when residual PPD of ≥ 6 mm was remaining at two or more tooth sites (OR 0.10; 0.11). CONCLUSIONS: The majority of periodontally involved maxillary molars had a substantially reduced interfurcal bone height, particularly with at least two sites with residual PPD ≥ 6 mm. This was a predictor for a subsequent need for sinus floor elevation when tooth replacement with a dental implant is desired.

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Is furcation involvement in maxillary molars a predictor for subsequent bone augmentation prior to implant placement? A pilot study.

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Running head: Furcation involvement predicts bone augmentation?

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Is furcation involvement in maxillary molars a predictor for subsequent bone augmentation prior to implant placement? [A pilot study](#).

Abstract

Aim: The aim of this [pilot](#) study was to analyze the interfurcal bone height in relation to the possible need for subsequent sinus floor elevation in patients with advanced periodontitis and furcation involvement of first and/or second maxillary molars.

Material and methods: 17 dentate patients, who received CBCT for detailed preoperative diagnosis and planning of surgical interventions at periodontally involved maxillary molars (17 first and 15 second molars), were consecutively recruited for the study. The minimal bone height in the interfurcal region was measured from CBCT and related to furcation involvement, residual bone above the root tips and to the clinical probing pocket depth (PPD).

Results: The minimal interfurcal bone height measured 4.1 ± 2.6 mm on average with 75% of maxillary molars having ≤ 6 mm and almost 60% having only ≤ 4 mm bone height left below the sinus floor. A higher risk for reduced interfurcal bone height of ≤ 4 mm was given when residual PPD of ≥ 6 mm were remaining at 2 or more tooth sites.

Conclusions: The majority of periodontally involved maxillary molars had a [significantly substantially](#) reduced interfurcal bone height, particularly with at least 2 sites with residual PPD ≥ 6 mm. This was a predictor for a subsequent need for sinus floor elevation when tooth replacement with a dental implant is desired.

Key words: Cone beam computed tomography, furcation involvement, Sinus floor augmentation, implant placement, maxillary sinus

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Introduction

Implant placement in the posterior maxilla is frequently limited due to a reduced bone height from an advanced alveolar ridge resorption and/or an increased pneumatization of the maxillary sinus (Boyne & James 1980, Zitzmann et al. 2010). To facilitate implant placement, vertical ridge augmentation and/or maxillary sinus grafting becomes inevitable. According to a clinical study, augmentation of the maxillary sinus with a crestal/ transalveolar approach using the “osteotome technique” with or without bone grafting material was recommended when more than 6 mm of residual bone height was present and an increase of about 3 to 4 mm was expected (Summers 1994, Zitzmann & Schärer 1998, Tan et al. 2008). In case of more advanced resorption with 4-6 mm residual bone height, the lateral antrostomy as a one-step procedure with simultaneous bone grafting and implant placement facilitated sufficient implant stability in most instances. With bone heights of only 4 mm or less, however, the 2-step lateral antrostomy with bone grafting was required, which prolonged the treatment period by at least 6 months (Zitzmann & Schärer 1998, Stern & Green 2012). For the vertical augmentation of a resorbed alveolar ridge, several techniques using autogenous bone grafts (such as inlay, onlay, or interpositional grafts), bone grafting materials, or distraction osteogenesis have been described (Stern & Green 2012, Schmitt et al. 2013). These augmentation procedures of the maxillary sinus and of the vertical ridge are associated with possible risks, particularly in patients with a history of periodontitis, general medical diseases and/or in smokers (Strietzel et al. 2007, Walter et al. 2011). When multiple risk factors are given, maintaining a compromised maxillary molar and avoiding extraction with subsequent augmentation is a significant therapeutic option. Hence, decision making in the posterior maxilla is a complex scenario, involving the medical and/or periodontal history, the smoking history, functional, anatomical and/or several tooth related aspects (Zitzmann et al. 2010).

Cone beam computed tomography (CBCT) has been introduced to dentistry several years ago (e.g. Mozzo et al. 1998). CBCT enables an exact estimation and classification of the furcation involvement, a visualization of decisive features, such as root proximities, root fusions or periapical lesions, and an assessment of the bone volume for implant treatment planning (Walter et al. 2009, Walter et al. 2010).

The aim of this preliminary study was to investigate the alveolar bone height remaining in furcation involved maxillary molars from CBCT to predict the frequency of sinus elevation procedures becoming necessary for later implant placement. Potential associations with tomographic and clinical periodontal parameters were analysed.

Material and Methods

17 dentate patients, who received CBCT for detailed preoperative diagnosis and planning of surgical interventions at periodontally involved maxillary molars, were consecutively recruited for the study. Recruitment was performed during April 2007 and January 2010 from the pool of patients at the Department of Periodontology, Endodontology and Cariology at the University of Basel, Switzerland. From the 17 patients enrolled, a total of 20 CBCT-scans were analyzed showing 17 first and 15 second periodontally involved molars. The patients were diagnosed for generalized advanced chronic periodontitis based on complete dental and periodontal examinations (including sensitivity testing of all teeth, probing pocket depth 'PPD', probing attachment level 'PAL', furcation involvement 'FI'), and radiographic examinations (periapical radiographs) (Walter et al. 2009). Patients had undergone periodontal pre-treatment and non-surgical periodontal therapy (scaling & root planing), and had residual PPD of ≥ 6 mm and/or advanced FI at the 6-month reevaluation indicating the need for periodontal surgery in the maxillary region. Advanced furcation involvement was defined as horizontal interradicular loss of periodontal tissues of degree II or III (Hamp et al. 1975). This retrospective study was approved by the Ethics Research Committee of the University of Basel, Switzerland (EK: 279/09). Patients were thoroughly informed about the study and the methods applied and gave their informed consent.

CBCTs were performed in the posterior maxillary area using the high resolution imaging system 3D Accuitomo 60 and 3D Accuitomo 80 (Morita, Kyoto, Japan). Cylindrical volumes of 4x4 cm, 6x6 cm and 8x8 cm, settings in the range of 74–90 kV, 5–8 mA and voxel size of 0.125 mm (2 lp/mm) were used depending on the region of interest. All images were analyzed at the same monitor (Viewmedic 19C, 48cm, 19°, Totoku, Japan). The software i-Dixel-3DX (Morita, Kyoto, Japan) with a linear measurement tool and a digital magnification lens was used. It facilitated a continuous motion with the cursor in the 3-dimensional area visualized in the three planes on the computer screen. CBCT images were analyzed in the [axial \(horizontal\)](#), sagittal and coronal [\(transversal\)](#) sections. The images were resliced in order to get an orthogonal examination plane through the respective tooth. All measurements were performed twice by one of the authors (D.D.B.) within one week, and an intraclass correlation coefficient (ICC) was determined to compare the repeated measurements of residual bone height (Shrout & Fleiss 1979). An ICC of 0.98 was calculated revealing a high similarity of the measurements.

The primary outcome parameter was the bone height in the interfurcal region, which was defined as minimal distance of the interradicular alveolar bone crest to the sinus floor (Fig. 1a). If possible, two measurements, i.e. in the sagittal and in the [coronal](#) plane, were

performed and combined as mean values for further analyses. It was assumed that a residual bone height in the furcation area of 4 mm or less would predict a sinus elevation procedure with a lateral antrostomy as staged approach, while more than 6 mm bone would facilitate conventional implant placement potentially combined with a transalveolar antrostomy („osteotome technique”). Data were then categorized in subgroups with 4 mm or less and more than 4 mm residual vertical bone height. In a second evaluation categories were made for 6 mm or less and more than 6 mm residual vertical bone height.

Further analyses investigated potential correlations with additional parameters:

- (i) the horizontal dimension of furcation involvement (FI) calculated in the [axial](#) plane of the CBCT by measuring the distance between the outer root surface and the interradicular bone to the nearest millimeter (Fig. 1b). FI was graduated according to Hamp et al. (1975) with degrees 0-III,
- (ii) the minimal bone height above the mesiobuccal, distobuccal and palatal root tip to the sinus floor in the [coronal](#) and sagittal plane of the CBCT (Fig. 1c),
- (iii) the clinical probing pocket depth (PPD), which was recorded for six sites of each tooth (mesiobuccal, buccal, distobuccal, distopalatal, palatal, mesiopalatal).

Statistical analysis

For the comparison of categorical variables counts and percentages were ~~detected~~[derived](#). Metric variables (e.g. age) were reported as means with standard deviation (SD) [and medians with interquartile ranges \(IQR\)](#). The level of significance was set at $\alpha=0.05$. To investigate the influence of the furcation involvement (FI) [on the primary outcome minimal interfurcal bone height](#), both the highest degree [of FI](#) was used for each tooth, and the number of FI degrees II and III per tooth was recorded. Similarly, both the highest PPD [value](#) as well as the number of PPD ≥ 6 mm were calculated for each tooth. These numbers of residual PPD ≥ 6 mm were categorized for each tooth as 1 with 0 or 1 site, 2 with 2 sites, and category 3 with 3 to 6 sites with PPD ≥ 6 mm. [To predict residual vertical bone heights \$>4\$ versus \$\leq 4\$ mm and \$>6\$ versus \$\leq 6\$ mm, logistic regression models were performed taking the minimal distance \$\leq 4\$ mm and \$\leq 6\$ mm as reference.](#) Because of the unbalanced occurrence of multiple teeth per subject, mixed-effects models [were lacking of intra-subject variability and were therefore omitted](#). Odds ratios and 95% CI's as well as the corresponding p -values were estimated. [While OR \$<1\$ indicate a higher risk of having \$\leq 4\$ mm or \$\leq 6\$ mm minimal interfurcal bone height, predictors with OR \$>1\$ reveal a higher probability of having \$>4\$ or \$>6\$ mm bone height in the interfurcal region.](#) All predictors were adjusted for gender and age and were separately analysed by univariate models. All analyses were performed with the statistical package R (Version 2.15.1, R Core Team 2012).

Results

The study group comprised 6 women and 11 men with a mean age of 56.5 ± 8.5 years. The minimal interfurcal bone height measured 4.1 ± 2.6 mm on average, 4.1 ± 2.9 mm for first and 4.0 ± 2.2 mm for second molars. The distribution of teeth according to their interfurcal bone height is presented in Table 1. With the threshold set at 4 mm, 19 teeth (59.4%) had a bone height of 4 mm or less, while 13 (40.6%) revealed more than 4 mm. With the level set at 6 mm, the majority with 24 teeth (75%) showed a bone height of ≤ 6 mm, while only 8 (25%) had more than 6 mm. The relative proportions of teeth in the subgroups ≤ 4 mm and >4 mm and in the subgroups ≤ 6 mm and >6 mm interfurcal bone height are shown in Fig. 2a and 2b, which illustrate the proportions in the different categories of PPD ≥ 6 mm.

For the subgroups ≤ 4 mm and >4 mm interfurcal bone height, small differences were observed for the maximal average values of PPD and FI (Table 2a, Fig. 2a). Among the teeth with ≤ 4 mm bone, the number of sites with PPD ≥ 6 mm amounted 2.16 on average, while among those with >4 mm bone, only a mean of 1.23 sites with PPD ≥ 6 mm were present. While the majority of teeth with ≤ 4 mm bone had 2 or more sites with PPD ≥ 6 mm (category 2 and 3), no or only one site with PPD ≥ 6 mm (category 1) was present in 8 of 13 teeth with >4 mm bone (Table 2a, Fig. 2a).

For the subgroups ≤ 6 mm and >6 mm interfurcal bone height, the differences among the categories of PPD ≥ 6 mm were smaller than for the 4 mm threshold. However, in the subgroup ≤ 6 mm a dominance of teeth with category 2 (2 sites with PPD ≥ 6 mm) was present with 12 out of 24 teeth (Table 2b, Fig. 2b). The bone height above the mesiobuccal root tip measured 1.3 mm in teeth with ≤ 6 mm bone height compared to 3.0 mm bone above the root tip of teeth with >6 mm bone height (Table 2b). For the palatal roots these differences between the subgroups were even larger with 1.38 mm (subgroup ≤ 6 mm) and 3.35 mm in the subgroup >6 mm interfurcal bone height.

The logistic regression applied for the subgroups ≤ 4 mm and >4 mm interfurcal bone height, revealed a significant difference for the PPD ≥ 6 mm categories 2 versus 1 (Table 3a, Fig. 3a). Teeth with two sites with PPD ≥ 6 mm (category 2) had a higher risk of presenting reduced interfurcal bone height of ≤ 4 mm than those with no or only one site with PPD ≥ 6 mm (OR 0.1, $p=0.03$). In the subgroups ≤ 6 mm and >6 mm interfurcal bone height, an impact of the amount of bone above the mesiobuccal and the palatal root tip was present (Table 3b, Fig. 3b). With more bone located between root tips and sinus floor, [the probability of having](#)

[more interfurcal bone \(>6mm\) increased, while the](#) risk of having reduced interfurcal bone height of ≤ 6 mm was smaller (mesiobuccal OR 3.0, $p=0.011$, palatal OR 1.72, $p=0.04$).

Discussion

The present cohort indicated that a reduced interfurcal bone height was present at maxillary molar teeth with 75% having ≤ 6 mm and almost 60% having only ≤ 4 mm vertical bone left below the sinus floor. Having at least 2 sites with clinical probing pocket depth of ≥ 6 mm was a predictor for a reduced interfurcal bone height of ≤ 4 mm. A higher risk existed also for reduced interfurcal bone height of ≤ 6 mm, when a reduced amount of bone was present above the mesiobuccal or palatal root tip.

[Recently, a first set of analyses from our patient cohort with CBCT data related to periodontally diseased molars in the maxilla was published \(Walter et al. 2009, Walter et al. 2010, Walter et al. 2012\).](#) The results of the current analysis in a population treated for advanced chronic periodontitis indicate a need for subsequent augmentation of the maxillary sinus in advance of [traditional well documented](#) implant placement [with implant length of 8-10mm](#) in at least 60% of the cases. It has to be noted that a certain bone remodelling of individually varying amounts can occur following tooth extraction and the need for bone augmentation procedures could even be greater than calculated for the present cohort. [Subsequent validation of the current presurgical data would be preferable, but could not be provided at this stage, since the majority of molars were maintained following successful periodontal therapy \(Walter et al. 2010\).](#)

The threshold of 4 and 6 mm has been applied in the current investigation according to previous studies, which documented that the lateral access is mostly required with less than 6 mm residual bone height and the staged approach may be indicated with less than 3-4 mm (Zitzmann & Schärer 1998, Rosen et al. 1999, Zinser et al. 2012). A recent survey of the dimensions of maxillary alveolar ridges following molar extractions using existing CBCT images was performed in 225 Asian Indian and 232 Hong Kong Chinese partially edentulous adults seeking tooth replacement. It was demonstrated that the available bone height in the sub-sinus region was affected by ethnicity, gender and sinus membrane thickening, while the residual ridge width was related to age and the presence of adjacent teeth (Acharya et al. 2014). [Furthermore, the vertical bone height alone is not the only decisive measure for the assessment of the type of surgery required for sinus floor elevation. The morphology of the sinus floor, i.e. flat or oblique, is also of importance. In an extended case series using 252 CBCT images of the edentulous posterior maxilla, the morphology of the sinus floor was](#)

evaluated in the vertical and horizontal dimensions (Nunes et al. 2013). A flat configuration was found in 53% of the edentulous sites, and a bony septum was present in 27%. In addition to these parameters, bone structure is another factor determining whether primary implant stability is feasible in conjunction with the grafting procedure or if staged implant placement is required. The extended treatment time of the staged implant installation reaching easily up to one year (Zinser et al. 2012), and the increased invasiveness and morbidity of grafting procedures, particularly when autogenous bone is harvested from a sound donor site (Nkenke & Stelzle 2009, Kahnberg et al. 2011, Jensen et al. 2012a, Zinser et al. 2012), are factors, which may not meet patient's expectations. Although rarely encountered, severe side effects can occur such as bleeding after maxillary sinus augmentation, infection with autogenous grafts and grafting materials, sinusitis, perforation of the sinus membrane and loss of the grafting material, which possibly impedes with later implant placement (Chiapasco et al. 2009, Jensen et al. 2012b). Even among dentists, there seems to be a certain aversion against sinus grafting. According to a recent questionnaire, 38% of the specialists and half of the general dentists did not support sinus grafting (against or indecisive) as a potential treatment option for themselves (Zitzmann et al. 2011).

For the maxillary posterior dentition, several treatment options with different invasiveness exist ranging from non-surgical and surgical periodontal treatment to tooth extraction and implant placement, contingently also requiring sinus augmentation. Evidence gained from clinical studies and systematic reviews comprising varying observation periods indicate promising outcomes for both periodontal therapy and implant treatment in combination with sinus grafting. For resective periodontal treatment in furcation involved molars a systematic review reported a wide range of 62-100% tooth survival after 5-9 years (Huynh-Ba et al. 2009), while even 93% survival had been achieved after 10 years in a clinical study, in which systematic treatment and maintenance was provided by master clinicians (Carnevale et al. 1998). Implants placed applying the transalveolar technique had 93% survival after 3 years (Tan et al. 2008), and 90% survival was found when implants were installed by the lateral sinus elevation approach (Pjetursson et al. 2008). While the timing of implant placement had no influence on the survival rates (with 88.5% in 1-staged and 90.9% in 2-staged implants at 3 years, Pjetursson et al. 2008), implant surface roughness and greater amounts of residual bone were positively related to implant survival (Pjetursson et al. 2008, Del Fabbro et al. 2012, Zinser et al. 2012). While bone grafting materials performed adequately in less atrophic cases, harvesting autogenous bone seemed to be required in highly atrophic situations (Zinser et al. 2012). In addition, the need for bone augmentation may decrease in the future due to the increased use of short implant lengths. Recent data from a systematic

review indicate promising results for short implants placed in the atrophic posterior maxilla but also indicate the need for further investigation (Corbella et al. 2013).

Additional factors other than basic implant survival rates have to be considered for decision making, in particular patient-reported outcome measures such as medical factors, treatment time and invasiveness, and financial consequences. Specifically, in patients with an increased risk for compromised wound healing or medical contra-indications for implant placement, avoidance of tooth extraction and/or traumatic bone grafting procedures is imperative (Zitzmann et al. 2009). Particularly patients with diabetes mellitus, smokers, and patients under intravenous bisphosphonate medication for more than 2 years (Balshi & Wolfinger 1999, Edwards et al. 2008) may be affected. In addition, smoking has been found to be a significant risk factor for implant treatment combined with augmentation procedures (Mayfield et al. 2001, Strietzel et al. 2007, Warnakulasuriya et al 2010). From an economic point of view, costs for implant placement in the augmented maxillary sinus including materials, temporary and final restorations obviously exceed the costs of the periodontal treatment (Walter et al. 2012).

Any research dealing with radiographic images inherits the risk of extending its indications, and thus increasing radiation exposure for the participants. This study was performed as a retrospective analysis of already existing CBCT images. Due to the limited indications for CBCT scans, the sample size was small, potentially causing some variation of the data as indicated by the standard deviations in the current analysis. In the current investigation, the basic principles on the use of CBCT of the European Academy of Dentomaxillofacial Radiology were implemented, the CBCT examinations were performed according to ALARA ("as low as reasonably achievable") and each indication was warranted by the diagnostic need for additional information affecting the subsequent treatment (EADMFR Guidelines, Horner et al. 2011).

Conclusion

The current data of this pilot study provide an estimate of the need of sinus floor elevation following extraction of periodontally involved maxillary molars and are an important measure to support decision making and to find adequate treatment options for the individual patient. In addition to the reduced interfurcal bone height, the degree of furcation involvement and the presence of increased probing pocket depth, i.e. PPD \geq 6mm, are potential clinical indicators for the need of subsequent augmentation prior to implant installation when molar extraction is required.

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Clinical Oral Implants Research

Legends of Figures and Tables

Fig. 1 Measurements performed from CBCT

- a) Assessment of the minimal interfurcal bone height
- b) Assessment of the horizontal dimension of furcation involvement
- c) Measurement of the minimal bone height above each root tip to the sinus floor

Fig. 2a Mosaic plot illustrating the relative proportions of teeth with ≤ 4 and > 4 mm minimal interfurcal bone height according to the category (1-3) with different numbers of PPD ≥ 6 mm per tooth

Fig. 2b Mosaic plot illustrating the relative proportions of teeth with ≤ 6 and > 6 mm minimal interfurcal bone height according to the category (1-3) with different numbers of PPD ≥ 6 mm per tooth

Fig. 3a Box plots for teeth with ≤ 4 and > 4 mm minimal interfurcal bone height according to the numbers of PPD ≥ 6 mm

Fig. 3b Box plots for teeth with ≤ 6 and > 6 mm minimal interfurcal bone height according to the bone above the mesiobuccal root tip

Table 1 Distribution of tooth sites (n, %) according to their minimal interfurcal bone height

Table 2a Descriptive data [with means \$\pm\$ standard deviation \(SD\) and median \(IQR\)](#) of possibly influencing factors at tooth sites with ≤ 4 versus > 4 mm minimal interfurcal bone height

Table 2b Descriptive data [with means \$\pm\$ standard deviation \(SD\) and median \(IQR\)](#) of possibly influencing factors at tooth sites with ≤ 6 versus > 6 mm minimal interfurcal bone height

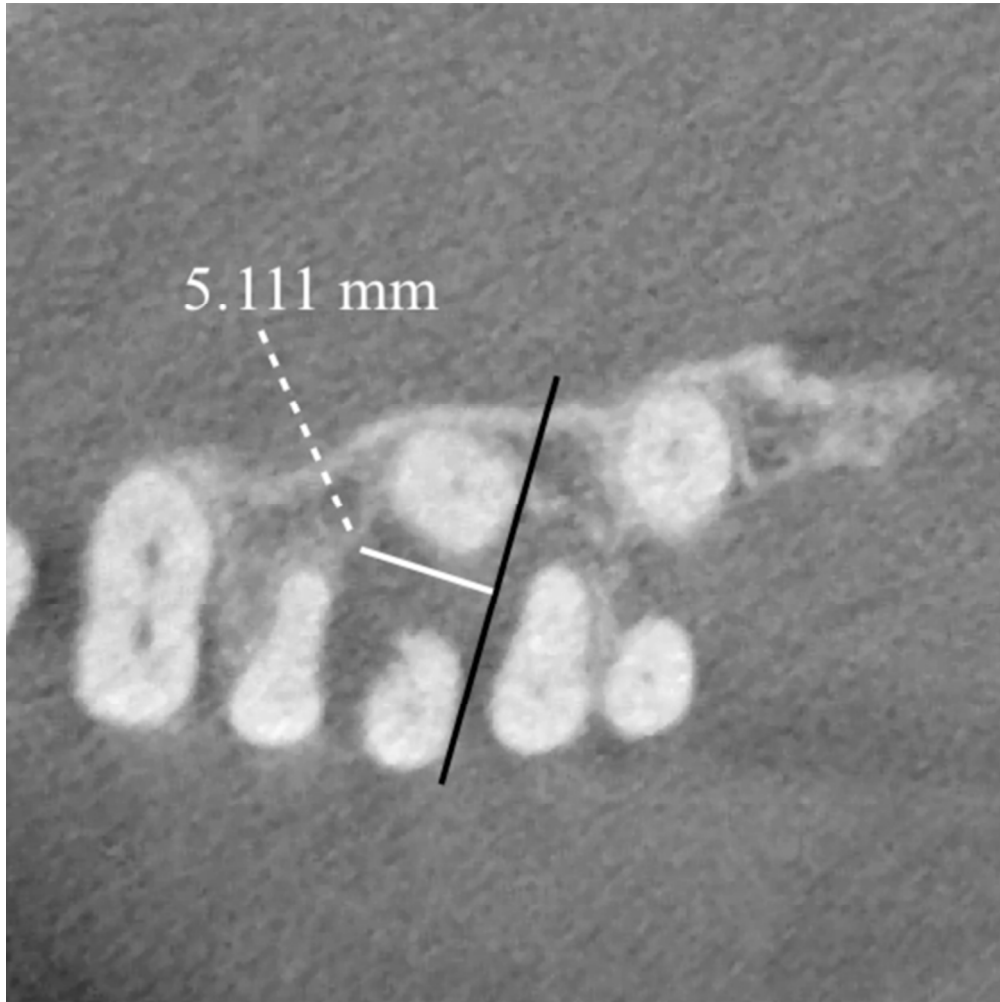
Table 3a Odds ratios and 95% CI at tooth sites with > 4 versus ≤ 4 mm minimal interfurcal bone height (from logistic regression models)

Table 3b Odds ratios and 95% CI at tooth sites with > 6 versus ≤ 6 mm minimal interfurcal bone height (from logistic regression models)



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Table 1 Distribution of tooth sites (n, %) according to their minimal interfurcal bone height

Bone height	1st molars (n=17)	2nd molars (n=15)	all, n (% of 32)
≤4mm	10 (52.6)	9 (47.4)	19 (59.4)
>4mm	7 (53.8)	6 (46.2)	13 (40.6)
≤6mm	12 (50)	12 (50)	24 (75)
>6mm	5 (62.5)	3 (37.5)	8 (25)

Table 2a Descriptive data with means \pm standard deviation (SD) and median (IQR) of possibly influencing factors at tooth sites with ≤ 4 versus > 4 mm minimal interfurcal bone height

Predictor	≤ 4 mm	> 4 mm	all
PPD maximal value	7.63 \pm 1.86; <u>8 (6.5, 9)</u>	6.38 \pm 1.94; <u>(4, 8)</u>	7.12 \pm 1.96; <u>(6, 8.25)</u>
PPD number ≥ 6 mm	2.16 \pm 1.17; <u>2 (2, 2.5)</u>	1.23 \pm 1.17; <u>1 (0, 2)</u>	1.78 \pm 1.24; <u>2 (1, 2)</u>
PPD ≥ 6 mm category 1 (n)	3	8	11
PPD ≥ 6 mm category 2 (n)	11	4	15
PPD ≥ 6 mm category 3 (n)	5	1	6
FI maximal value	3.47 \pm 0.77; <u>4 (3, 4)</u>	3.38 \pm 1.04; <u>4 (3, 4)</u>	3.44 \pm 0.88; <u>4 (3, 4)</u>
FI number degree II and III	2 \pm 1.2; <u>3 (1, 3)</u>	2 \pm 1.29; <u>3 (1, 3)</u>	2 \pm 1.22; <u>3 (1, 3)</u>
Bone above root tip mesiobuccal	1.46 \pm 0.76; <u>1.24 (1.01, 1.77)</u>	2.17 \pm 1.76; <u>1.17 (0.93, 3.69)</u>	1.75 \pm 1.29; <u>1.2 (0.95, 2.41)</u>
distobuccal	1.67 \pm 1.17; <u>1.1 (0.94, 2.05)</u>	1.89 \pm 1.55; <u>1.17 (0.76, 2.58)</u>	1.75 \pm 1.31; <u>1.13 (0.94, 2.31)</u>
palatal	1.52 \pm 1.12; <u>0.99 (0.79, 2.17)</u>	2.39 \pm 2.66; <u>1.1 (0.82, 2.7)</u>	1.88 \pm 1.91; <u>1.03 (0.81, 2.47)</u>

Table 2b Descriptive data with means \pm standard deviation (SD) and median (IQR) of possibly influencing factors at tooth sites with ≤ 6 versus > 6 mm minimal interfurcal bone height

Predictor	≤ 6 mm	> 6 mm	all
PPD maximal value	7.29 \pm 1.97; <u>8 (6, 8.25)</u>	6.62 \pm 2.0; <u>6.5 (5.5, 8.25)</u>	7.12 \pm 1.96; <u>8 (6, 8.25)</u>
PPD number ≥ 6 mm	1.88 \pm 1.23; <u>2 (1, 2)</u>	1.50 \pm 1.31; <u>1.5 (0.75, 2)</u>	1.78 \pm 1.24; <u>2 (1, 2)</u>
PPD ≥ 6 mm category 1 (n)	7	4	11
PPD ≥ 6 mm category 2 (n)	12	3	15
PPD ≥ 6 mm category 3 (n)	5	1	6
FI maximal value	3.33 \pm 0.92; <u>4 (3, 4)</u>	3.75 \pm 0.71; <u>4 (4, 4)</u>	3.44 \pm 0.88; <u>4 (3, 4)</u>
FI number degree II and III	1.79 \pm 1.22; <u>2 (1, 3)</u>	2.62 \pm 1.06; <u>3 (3, 3)</u>	2 \pm 1.22; <u>3 (1, 3)</u>
Bone above root tip mesiobuccal	1.34 \pm 0.72; <u>1.07 (0.91, 1.45)</u>	2.98 \pm 1.83; <u>3.09 (1.27, 4.4)</u>	1.75 \pm 1.29; <u>1.2 (0.95, 2.41)</u>
distobuccal	1.51 \pm 1.09; <u>1.06 (0.88, 1.65)</u>	2.49 \pm 1.72; <u>2.23 (1.14, 3.39)</u>	1.75 \pm 1.31; <u>1.13 (0.94, 2.31)</u>
palatal	1.38 \pm 1.03; <u>0.95 (0.79, 1.63)</u>	3.35 \pm 3.05; <u>2.15 (1.37, 5.31)</u>	1.88 \pm 1.91; <u>1.03 (0.81, 2.47)</u>

Categories with number of PPD ≥ 6 mm per tooth as 1 with 0 or 1 site, 2 with 2 sites, and category 3 with 3 to 5 sites with PPD ≥ 6 mm

Table 3a Odds ratios and 95% CI at tooth sites with >4 versus ≤4 mm minimal interfurcal bone height (from logistic regression models)

Predictor	OR	95% CI	p-value
PPD maximal value	0.71	0.46-1.10	0.11
PPD number ≥6mm	0.52	0.24-1.16	0.079
PPD ≥6mm category 2 vs. 1	0.10	0.01-0.80	0.03*
PPD ≥6mm category 3 vs. 1	0.11	0.01-1.51	0.10
FI maximal value	0.73	0.26-2.04	0.55
FI number degree II and III	0.91	0.46-1.80	0.78
Bone above root tip mesiobuccal	1.62	0.84-3.15	0.13
distobuccal	1.16	0.64-2.12	0.63
palatal	1.29	0.83-1.99	0.24

Table 3b Odds ratios and 95% CI at tooth sites with >6 versus ≤6mm minimal interfurcal bone height (from logistic regression models)

Predictor	OR	95% CI	p-value
PPD maximal value	0.87	0.57-1.32	0.50
PPD number ≥6mm	0.85	0.42-1.73	0.65
PPD ≥6mm category 2 vs. 1	0.48	0.08-3.04	0.44
PPD ≥6mm category 3 vs. 1	0.51	0.04-6.96	0.62
FI maximal value	2.0	0.58-6.88	0.27
FI number degree II and III	2.35	0.84-6.6	0.11
Bone above root tip mesiobuccal	3.0	1.25-7.18	0.014*
distobuccal	1.83	0.92-3.63	0.083
palatal	1.78	1.01-3.12	0.044*

*indicates statistical significant difference

Categories with number of PPD ≥6mm per tooth as 1 with 0 or 1 site, 2 with 2 sites, and category 3 with 3 to 5 sites with PPD ≥6mm

Fig. 2a Mosaic plot illustrating the relative proportions of teeth with ≤ 4 and >4 mm minimal interfurcal bone height according to the category (1-3) with different numbers of PPD ≥ 6 mm per tooth

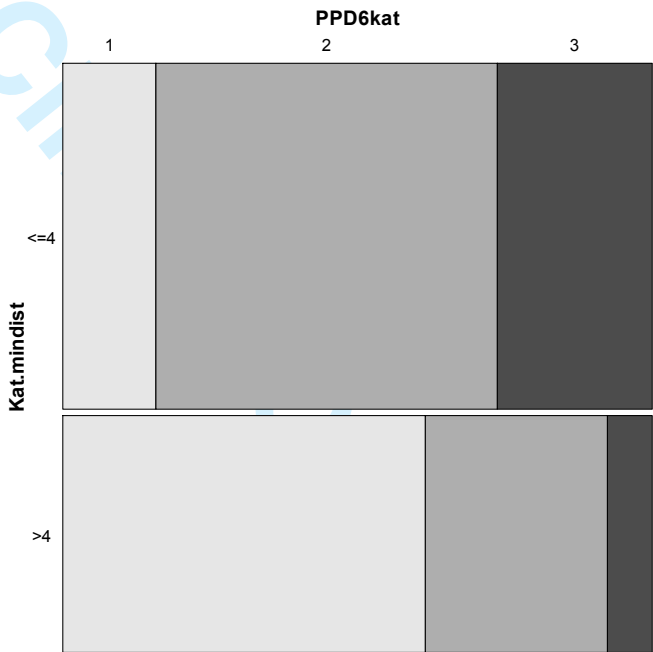
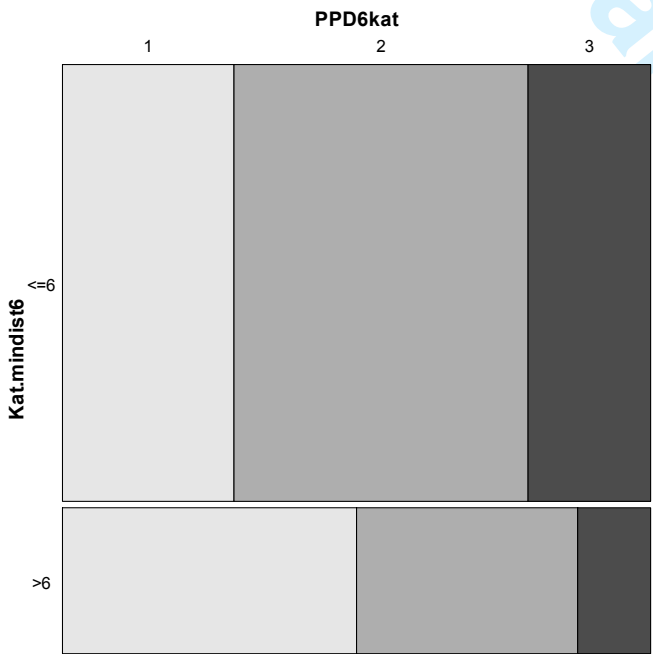


Fig. 2b Mosaic plot illustrating the relative proportions of teeth with ≤ 6 and >6 mm minimal interfurcal bone height according to the category (1-3) with different numbers of PPD ≥ 6 mm per tooth



Categories with number of PPD ≥ 6 mm per tooth as 1 with 0 or 1 site, 2 with 2 sites, and category 3 with 3 to 5 sites with PPD ≥ 6 mm

Fig. 3a Box plots for teeth with ≤ 4 and >4 mm minimal interfurcal bone height according to the numbers of PPD ≥ 6 mm

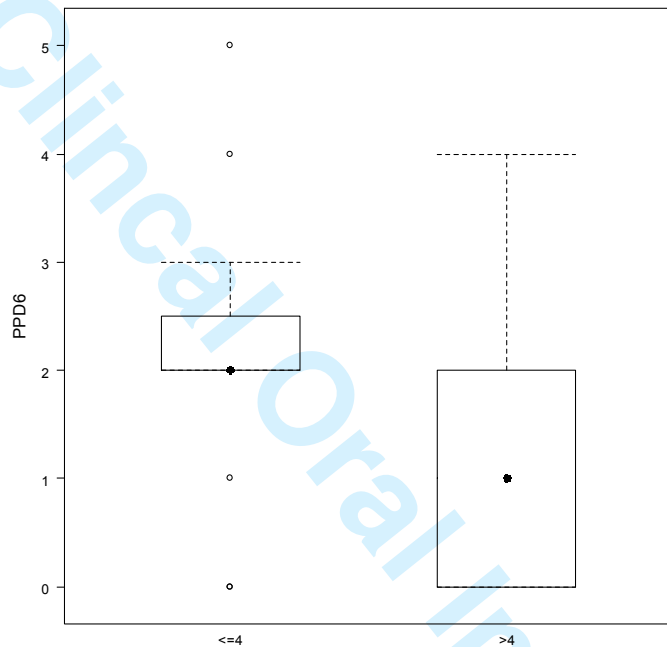
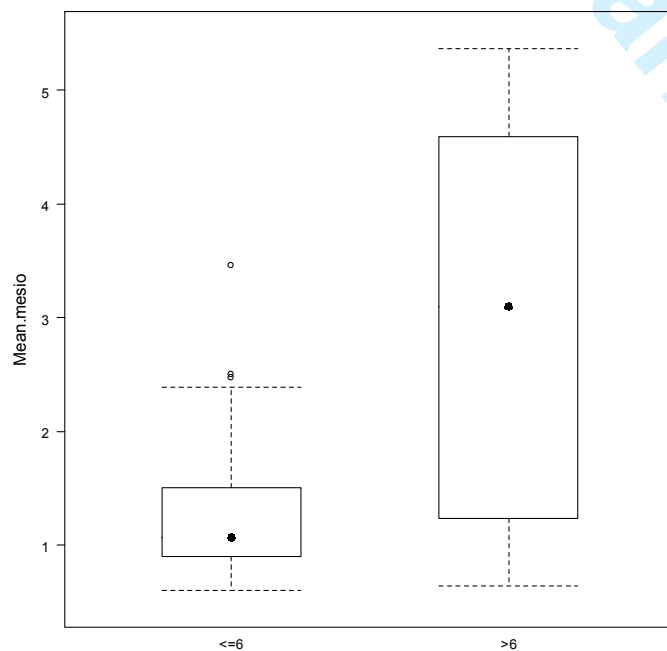


Fig. 3b Box plots for teeth with ≤ 6 and >6 mm minimal interfurcal bone height according to the bone above the mesiobuccal root tip



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Präsidentin der Prüfungskommission Zahnmedizin Schweiz

Basel, August 26th, 2013

Dear Professor Lang, dear Niklaus
please find enclosed our second revision of the manuscript entitled
"Is furcation involvement in maxillary molars a predictor for subsequent bone augmentation prior to implant
placement? A pilot study.",
which had been submitted for publication in the *Clinical Oral Implants Research*.

We want to thank the statistical reviewer for the valuable comments and included the considerations in the present
revision.
Thanking you in advance, best personal regards, Nicola Zitzmann and Clemens Walter

Statistical Advisor: 1
Comments on the statistics of the paper 13-OR-3535R1 By Walter et al.

ad 1) *The authors investigate in this pilot study the interfurcal bone height in 17 patients using CBCT. The data are clustered within a patient. Hence, mixed models were applied. Because of statistical problems the dependence of the data was neglected. Please mention the difference of the result of these two analyses.*

Thank you for this comment. We have to apologize that this point was not sufficiently clarified:
Due to the occurrence of one or two teeth per subject, mixed-effects models were used in a first step. In the categories with 6mm or less and more than 6mm residual vertical bone height in the furcation, the unbalanced occurrence of multiple teeth per subject resulted in a lack of intra-subject variability (and no differences between the 2 methods can be provided here). Hence, the mixed model was discarded and only logistic regression analysis was applied for both >4 versus ≤4 and >6 versus ≤6mm interfurcal bone heights.

We have corrected the manuscript accordingly:
„To predict residual vertical bone heights >4 versus ≤4mm and >6 versus ≤6mm, logistic regression models were performed taking the minimal distance ≤4mm and ≤6mm as reference. Because of the unbalanced occurrence of multiple teeth per subject, mixed-effects models were lacking of intra-subject variability and were therefore omitted.”

ad 2) *I think one used the indicator of >4mm resp. >6mm in the logistic regression. Did one model the 1 or the 0? What means the OR<1, in favour of ? One might apply a multiple logistic regression including several predictors to investigate their joint impact.*



Thank you for this comment. We clarified in the Statistical methods section:

"To predict residual vertical bone heights >4 versus ≤ 4 mm and >6 versus ≤ 6 mm, logistic regression models were performed taking the minimal distance ≤ 4 mm and ≤ 6 mm as reference."

For better understanding, we added:

"While OR <1 indicate a higher risk of having ≤ 4 mm or ≤ 6 mm minimal interfurcal bone height, predictors with OR >1 reveal a higher probability of having >4 or >6 mm bone height in the interfurcal region."

In the result section and in Tables 3a and 3b, we explained:

"The logistic regression applied for the subgroups ≤ 4 mm and >4 mm interfurcal bone height, revealed a significant difference for the PPD ≥ 6 mm categories 2 versus 1 (Table 3a, Fig. 3a). Teeth with two sites with PPD ≥ 6 mm (category 2) had a higher risk of presenting reduced interfurcal bone height of ≤ 4 mm than those with no or only one site with PPD ≥ 6 mm (OR 0.1, $p=0.03$). In the subgroups ≤ 6 mm and >6 mm interfurcal bone height, an impact of the amount of bone above the mesiobuccal and the palatal root tip was present (Table 3b, Fig. 3b). With more bone located between root tips and sinus floor, the probability of having more interfurcal bone (>6 mm) increased, while the risk of having reduced interfurcal bone height of ≤ 6 mm was smaller (mesiobuccal OR 3.0, $p=0.011$, palatal OR 1.72, $p=0.04$)."

ad 3) Please change on page 6 line 32 'detected' to 'derived'.

Changed accordingly: "For the comparison of categorical variables counts and percentages were derived." (or "calculated")

ad 4) A pilot study does not have the aim to find significant results. It should provide an interesting description of the findings for further studies. And neglecting the dependence of the data might be accepted in the analyses of a pilot study.

Thank you for this comment. Besides the report of pure data in the result section, we tried to avoid insisting on significances in this pilot study as suggested by the reviewer. Hence, we changed the wording in the abstract:

"Conclusions: The majority of periodontally involved maxillary molars had a substantially reduced interfurcal bone height, particularly with at least 2 sites with residual PPD ≥ 6 mm."